ATTRIBUTION OF TRENDS AND VARIABILITY IN SURFACE OZONE OVER THE UNITED STATES

Sarah Strode, Owen Cooper, Megan Damon, Jennifer Logan, Jose Rodriguez, Susan Strahan, Jacquie Witte

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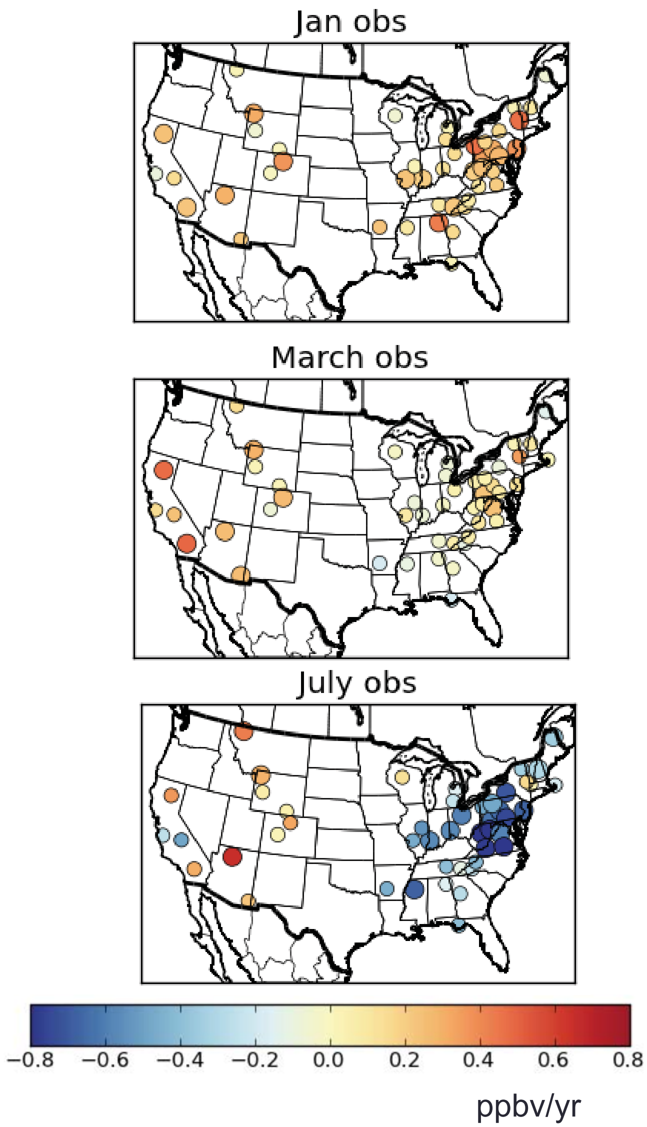
Introduction

- CASTNET observations of surface O_3 from 1990-2010 [*Cooper et al.,* 2012] show:
  - negative trends in the eastern U.S. in summer, especially at the high end of the O_3 distribution; mixed trend directions in the western U.S.
  - Positive trends throughout US in winter & in western US in Spring
- Global model can reproduce E-W gradient in summer trends but not magnitude of western US trends [*Koumoutsaris & Bey,* 2012]
- Can a global model w/ interactive stratosphere reproduce the trends and inter-annual variability (IAV) in U.S. surface O_3 in different regions and seasons?
- How much do changes in emissions contribute to the trends? Strat-trop exchange?

Surface O_3 1991-2010 trend



Model and Observations

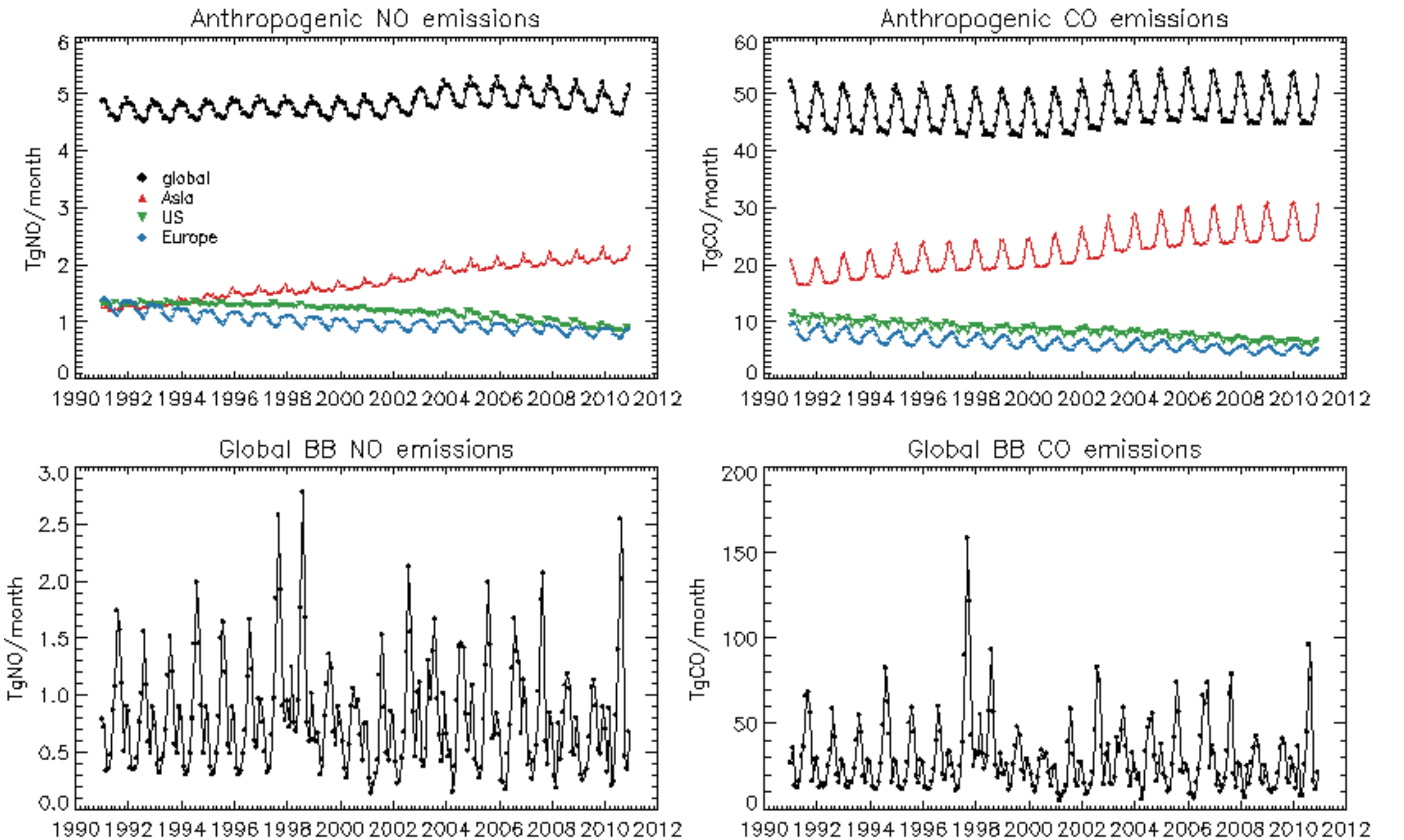
- Hourly observations from EPA Clean Air Status and Trends Network (CASTNET) rural surface stations, filtered as in *Cooper et al.* [2012]
- Mean, median, 5^{th} & 95^{th} percentile calculated for each month using all mid-day (11am-4pm) data
- GMI Chemical Transport Model (Duncan et al., 2007; Strahan et al., 2007) simulations of 1990-2010
  - Meteorology from the MERRA reanalysis
  - 2x2.5 degree horizontal resolution, 72 vertical levels
  - Stratospheric and tropospheric chemistry w/ 117 species, 400+ reactions
  - IGAC stratospheric SAD accounts for Pinatubo
  - Hourly output at station locations selected for mid-day hours

Emissions

- Standard simulation has time-dependent emissions
  - Biomass burning from GFED3 for 1997-2010; regional IAV based on *Duncan et al.* (2003) for 1990-1996
  - Anthropogenic emissions from EDGAR overwritten with NEI2005, EMEP, *Zhang et al.* (2009)
  - Annual scaling factors from GEOSChem for anthropogenic emissions (*van Donkelaar et al.*, 2008) for 1990-2006
  - 2007-2010 include annual scaling of whole U.S. based on NOx and CO emissions totals from EPA; REAS projections over Asia
  - 71% increase in Asian NO_x, 33% decrease in US NO_x for 1991-2010
- Sensitivity simulation with fixed emissions

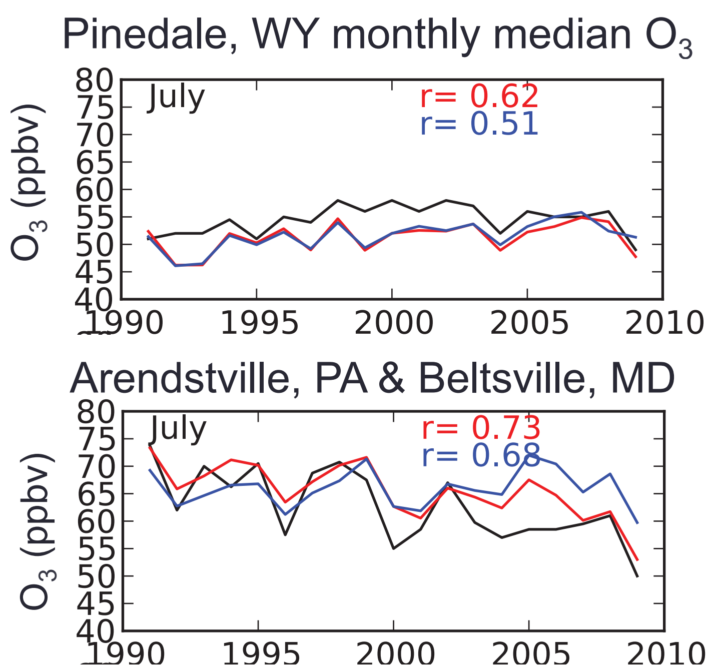
Simulation	Anthro Emis	Biomass Burning
Standard	IAV	IAV
EmFix	Fixed at Y2000	Fixed at Y2000

Emissions Time Series



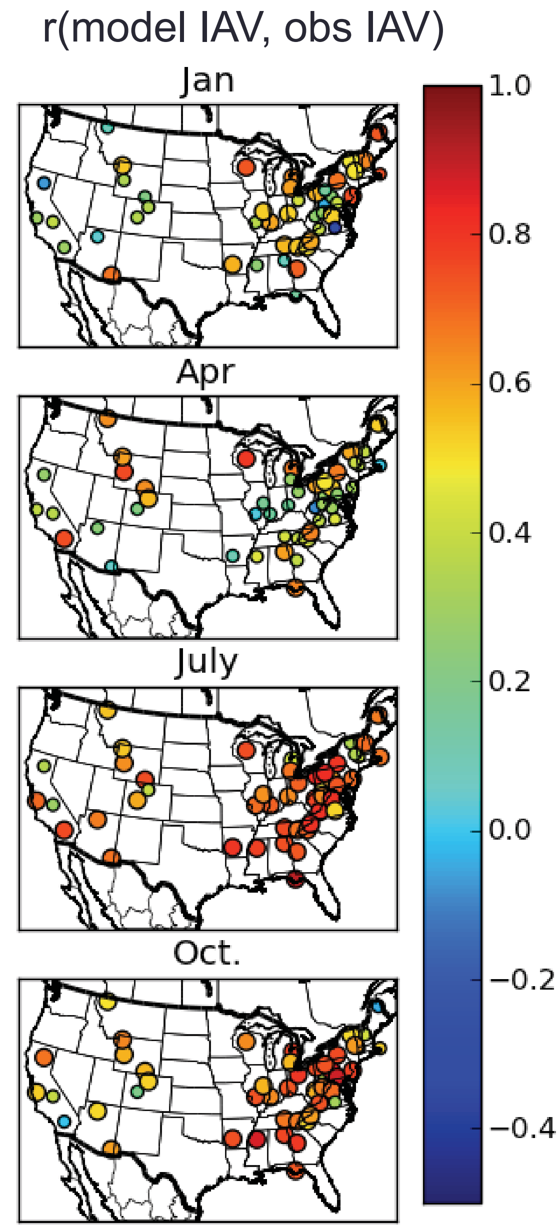
Modeled vs. Observed IAV

- Significant correlation of modeled and observed detrended IAV of median monthly O_3 at many stations
- Magnitude of variability underestimated
- Best correlations at eastern sites in summer, median or 95th percentiles
- Similar correlations in standard sim & EmFix



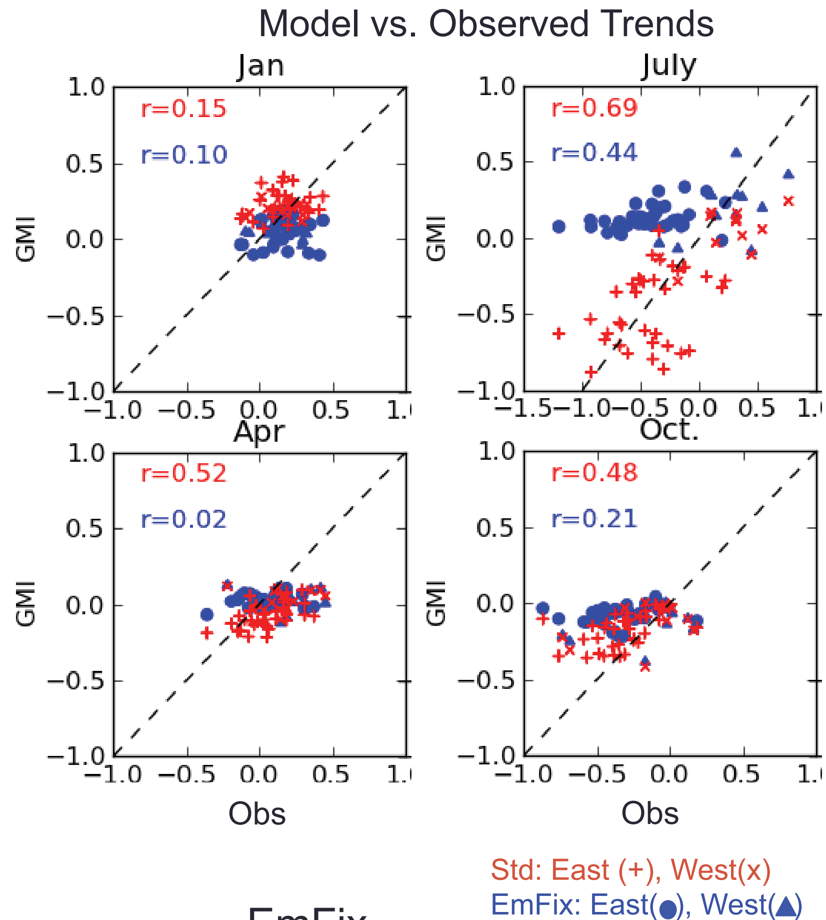
Observations
Standard (time-dependent emissions)
emFix (fixed emissions)

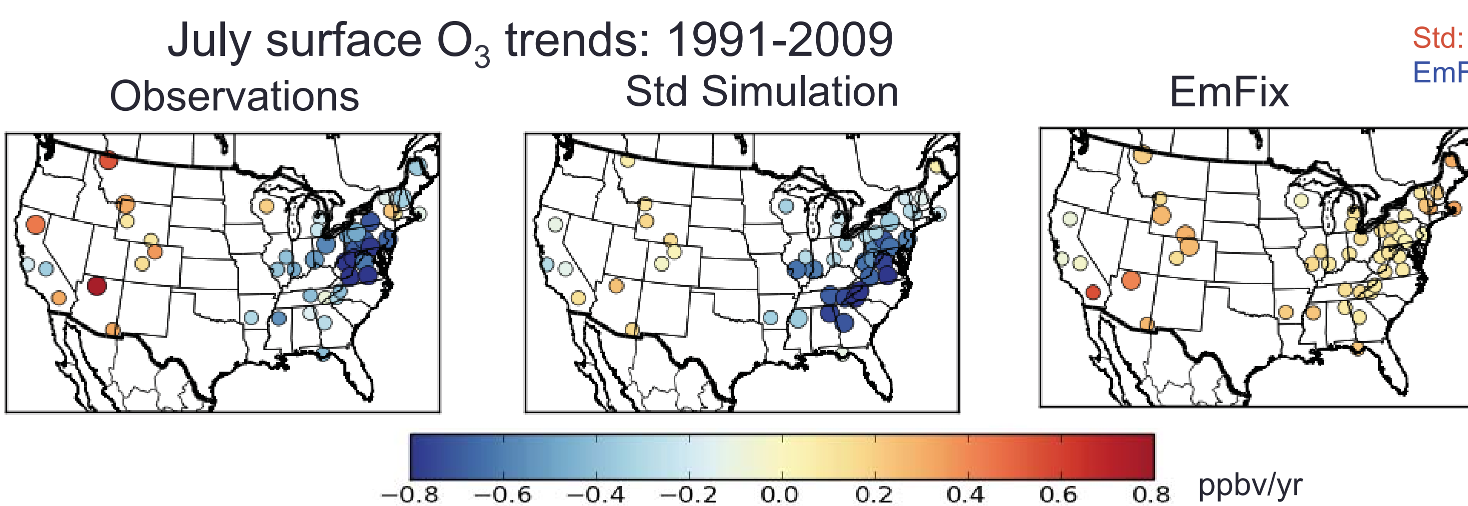
Large circles: r is significant
Small circles: r not significant



Summer Trends

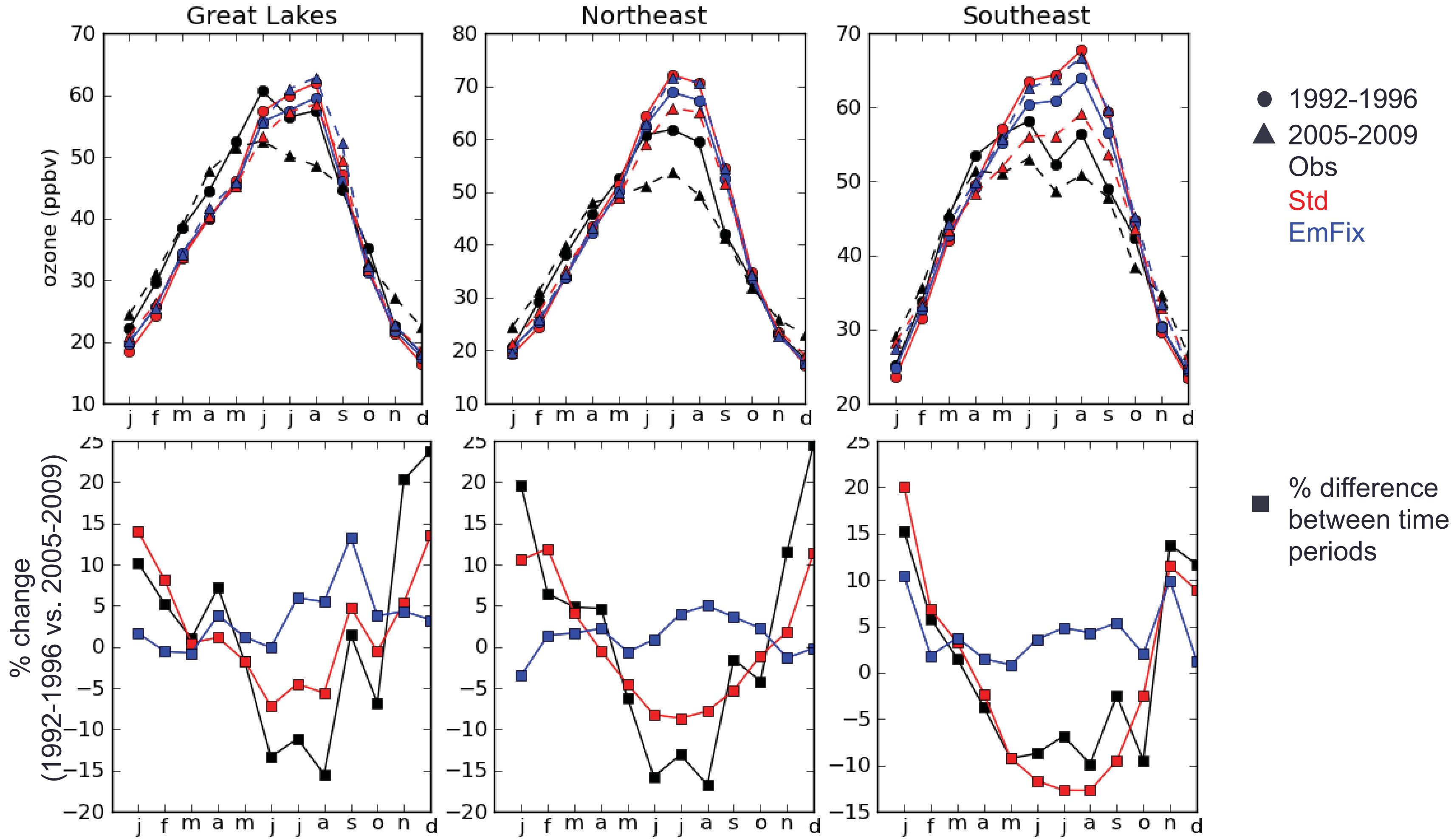
- East-West gradient in summer trends captured by standard simulation but not EmFix simulation → key role for emission reductions
- Model underestimates magnitude of western trends





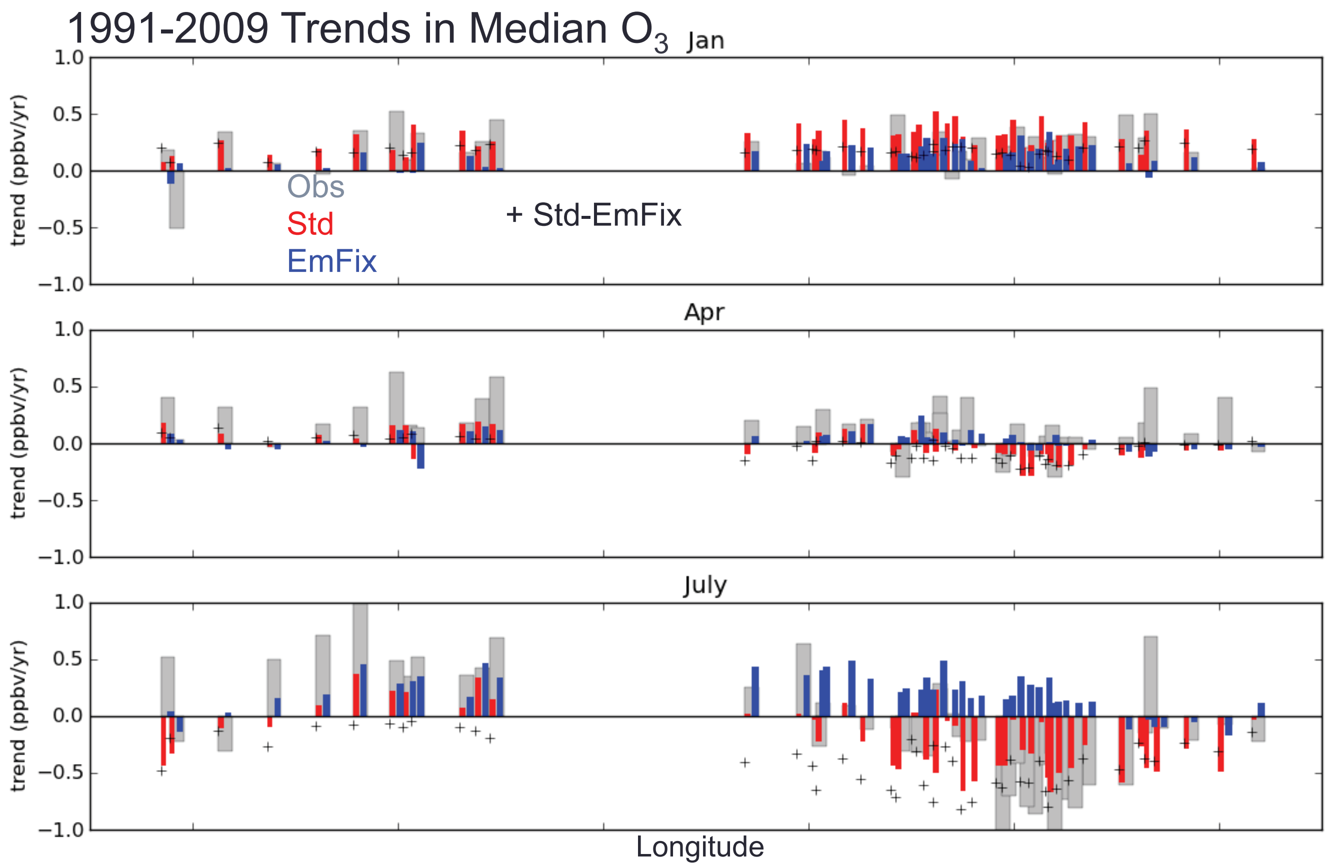
Shift in Seasonal Cycle

- Observed shift in seasonal cycle from summer peak to broader spring-summer max [*Cooper et al.*, 2012]
- Standard simulation captures shift better than EmFix



Positive Trends in West and Winter

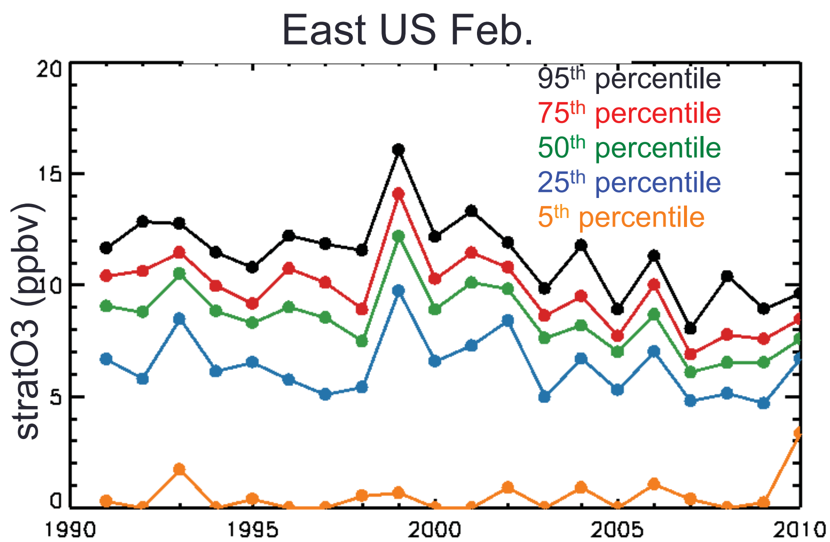
- Western trends more variable than eastern
- Positive trends due to changes in Asian, biomass burning, or local emissions? Stratosphere-troposphere exchange (STE)? Meteorology?

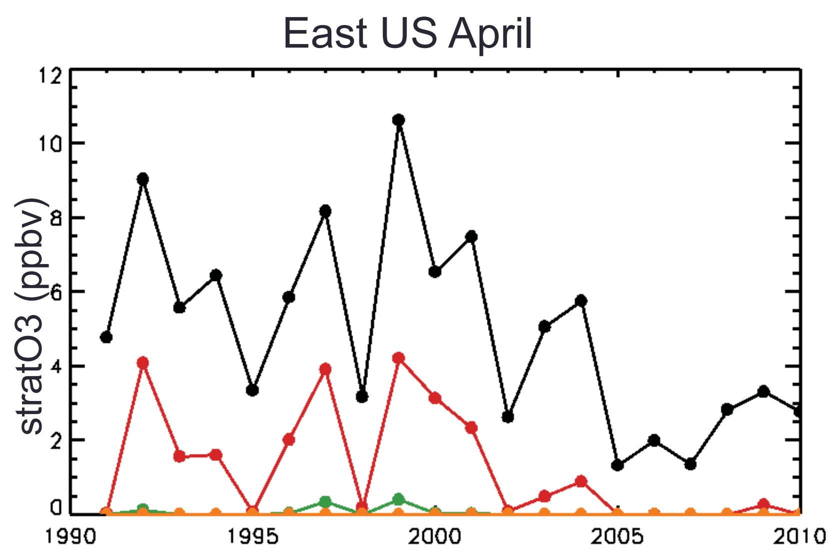


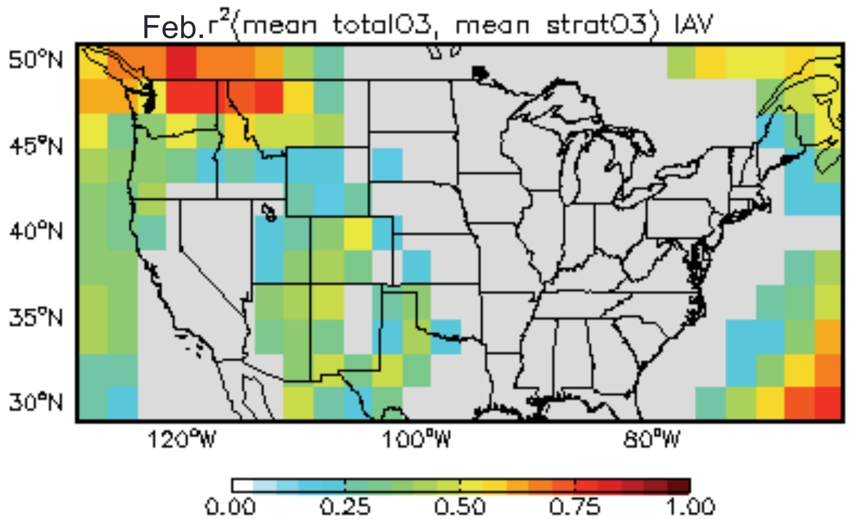
- Better agreement of Standard simulation in winter shows role for rising Asian emissions, while positive trends in EmFix in Summer show role for other factors
- Spring trends poorly captured → emission trends underestimated?

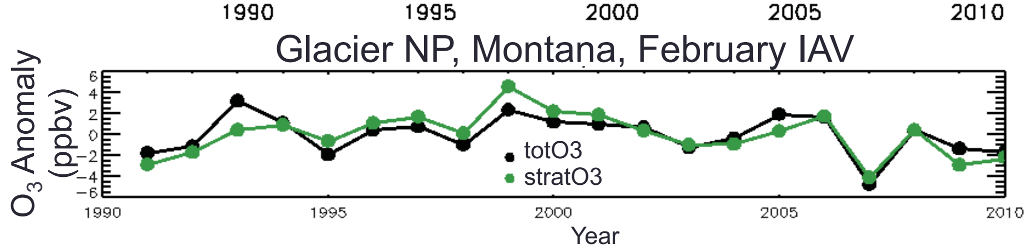
Strat-Trop Exchange

- Model stratO3 tracer equals O_3 above e90 tropopause, chemical loss in the troposphere
- No significant positive trends at the surface over the US for 1991-2010
- Significant negative trend in 50th-95th percentiles of east US stratO3 in Jan-March, 75th and 95th percentile in April
- Does not explain model's positive western US trends, but significant correlations between total & stratO3 winter IAV in west









Conclusions & Future Work

- 20-year hindcast captures east-west gradient in US summer ozone trends and the shift in seasonality toward a broader spring-summer max when time-dependent emissions are included
- Model underestimates positive trends in western US in spring and winter (and overestimates eastern trends in winter)
- Examined role of interactive stratosphere on modeled trends & IAV: No significant positive trend in monthly mean stratO3 at surface; negative trend in high percentile surface stratO3 over the eastern US

Future work:

- Conduct simulation with larger emission increase over Asia & spatially-varying emission changes over US based on satellite NO_2 (*Lamsal et al.*, 2011)
- Quantify ozone trends on days with large Asian influence
- Examine impact of model resolution

Proposed – current 2010 NO_x emissions